Structural Integrity Monitoring for Improved Drinking Water Infrastructure Sustainability

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THE ISSUE

Water main breaks/leaks pose risks to drinking water quality, quantity, reliability, and affordability

- ≈ 240,000 main breaks/yr in ≈ 880,000 mi of U.S. water mains
- Adverse effects from main breaks/leaks can include – pressure loss; contaminant backflow and intrusion; waterborne disease outbreaks; boil water orders; water supply depletion; disruption of water supply for consumption, sanitation, industry, and fire protection; deferral of maintenance; accelerated corrosion; bedding erosion; emergency response costs; lost revenue; damage to distribution system, other infrastructure, and private property; disruption of residential, commercial, industrial, and transportation activities; and liability

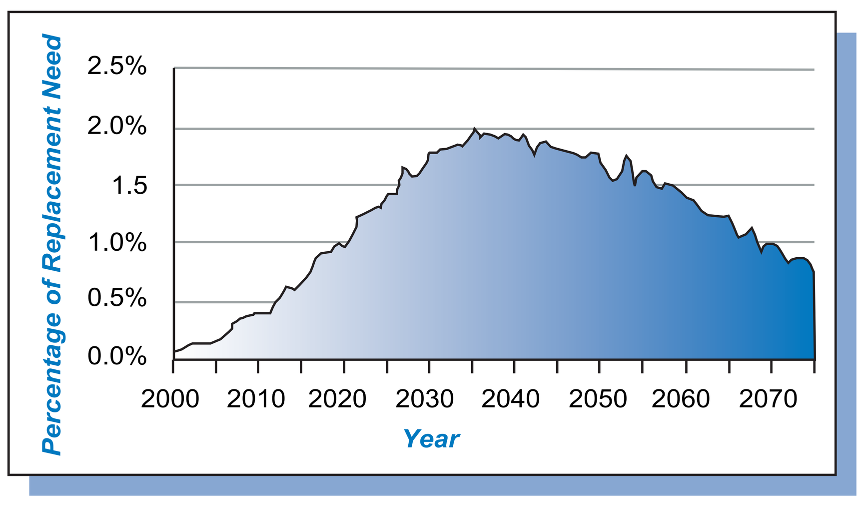
High risk main breaks and leaks are of particular concern

- They cause major adverse effects to customers, surroundings, and/or the drinking water distribution system itself

- Survey of 70 systems reported 11,186 pressure reduction incidents in the past year.... 19.2% were due to main breaks...
- Water main break allowed back-siphonage from a pest control company service connection into the public water system - 1987, NJ
- 4 deaths, 32 hospitalized, 232 illnesses from *E.coli* contamination from sewage overflow entering distribution system via main breaks and meter replacements - 1989, Cabool, MO
- 15 to 20 M gal lost/ $ 2 M emergency repair- 1996, Cranston, RI
- Roadway flooding, hydroplane accidents - 2002, Fort Worth, TX
- $ 2M for structure and content damages - 2001, Dallas, TX
- Electrical service flooded; 26,000 homes lost power for 1 day - 2003, Philadelphia, PA

U.S. water mains may be on the verge of a significant increase in structural failures

- Failures increase as mains reach the ends of service lives
- Large fraction of U.S. drinking water mains nearing end of service life
- Substantial replacement costs projected



- Not feasible to upgrade all water mains at once
  - Mains are >50% of drinking water infrastructure value
  - Increasing replacement need is projected for the next 30 years
  - Peak projected replacement rate is >4x current rate

Repair, rehabilitation, and replacement (R3) of "worst mains first" reduces failures and maximizes utilization. Inadequate detection, location, and quantification of damage and deterioration indicators, i.e., inadequate structural integrity monitoring (SIM) hinders efficient scheduling of R3

RESOLVING THE ISSUE

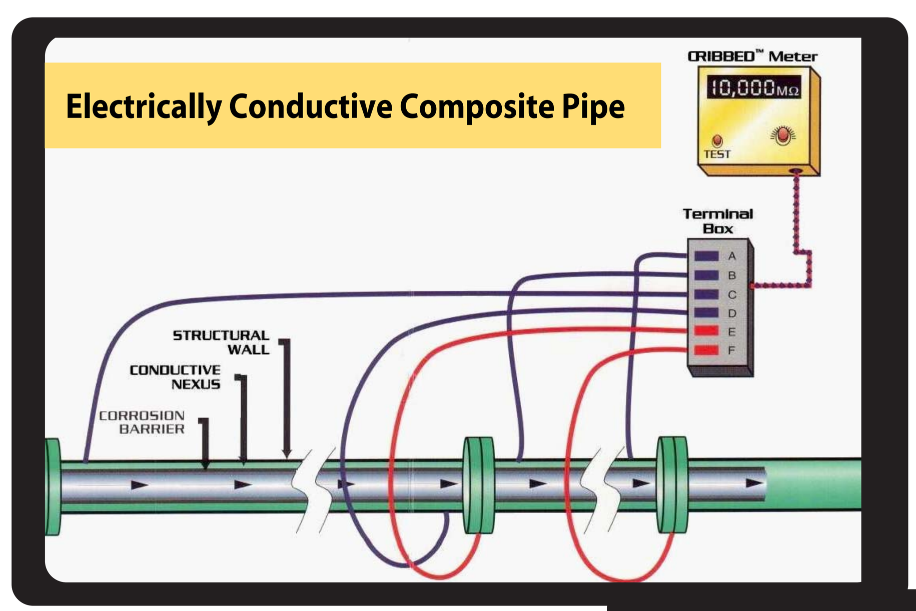
Reduce high risk drinking water main failures and their adverse effects by accelerating the improvement and use of SIM

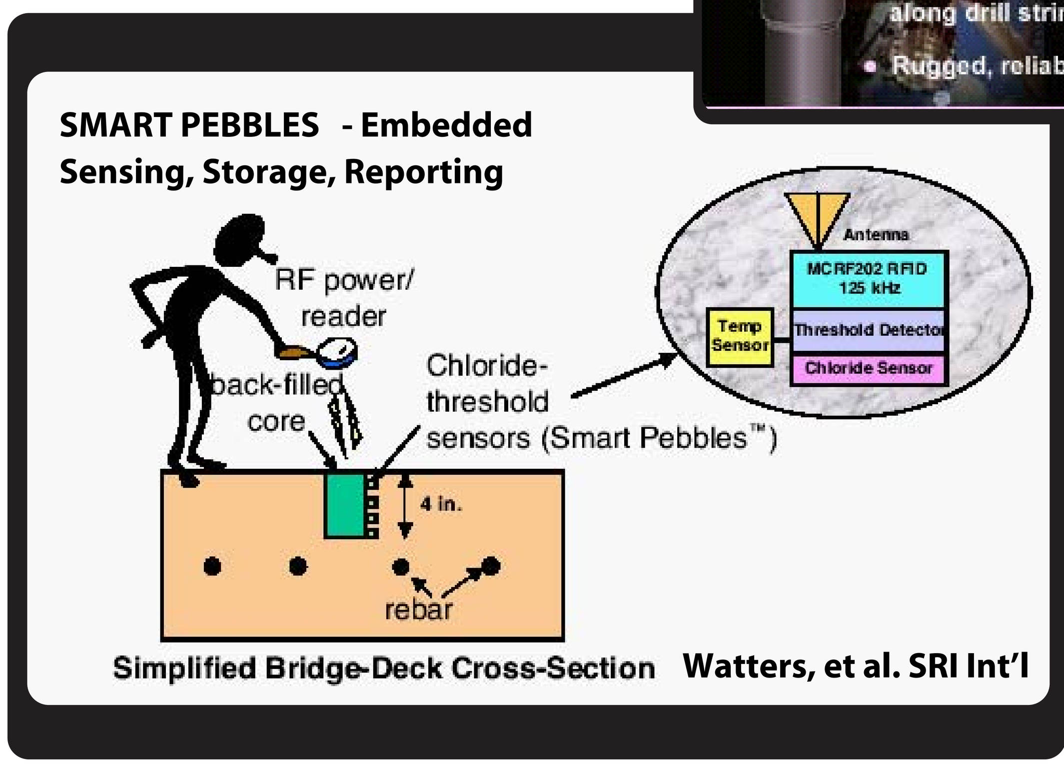
SIM APPROACHES	
Reactive Approach Monitor Water Quality Excavate & Evaluate Hydrotest Leak Detection & Location Hydraulic Parameter Monitoring	Cathodic Protection Statistical Models Short-term Structural Monitoring In-Line Inspection (Person-entry, Smart Pigs) Intelligent/Embedded SIM Systems (Emerging)

WEAKNESSES OF EXISTING SIM APPROACHES	
Post-Failure Detection Inadequate Sensitivity Poor Location Accuracy Labor Intensive Slow	Interruptive Intrusive Limited Coverage (e.g., area, material, flaw, time) No Condition Assessment No Performance or Cost History

SIM improvements for other applications provide many technology transfer opportunities

SIM IMPROVEMENTS	
PERFORMANCE	COST
Detection limit & sensitivity Sampling rate/duration/reliability Inspectible fraction of the system Flaw types that can be detected Data screening capability Data transmission rates Energy supply options	Mobilization/demobilization Pipe preparation and cleanup Equipment acquisition and maintenance Energy Remote, automatic, continuous operation capabilities





Identify performance and cost targets for next-generation SIM technologies

HIGH CONSEQUENCE MAIN BREAK SCENARIOS		
Critical Customers	Large populations Defense facilities Key industry	Hospitals Fire protection
Critical Surroundings	Industrial/Commercial/Residential Road/Bridge/Tunnel/Rail/Subway/Airport Water Mains/Critical Sewers/Communications Energy pipelines/cables	
Difficult Response	Large mains Difficult terrain Heavy traffic	Remote River crossing Extreme Temperature

Indicators of potentially preventable main breaks:

- Leaks that cause erosion & detectable excess strain
- Soil movement that causes excess strain
- Increasing leak rates
- Excessive wall thinning
- Excessive pitting
- Partial, localized structural failures (e.g. cracking)
- Coating failure that changes pipe electrical properties
- Cathodic protection partial or total failure

Generate research objectives for reaching performance and cost targets

- Collaborate with users, manufacturers, federal/non-federal researchers
- Include near-term, mid-term, long-term goals
- Rank performance and cost targets

Develop and execute federal research and technology transfer plan

- Complement non-federal research
- Accelerate completion of SIM performance and cost targets
- Maximize tech transfer from related federal research
- Maximize use of existing federal programs, facilities, expertise

Publish performance and cost data and produce guidance on SIM technology selection

COLLABORATION

COLLABORATION OPPORTUNITIES
Intra-EPA - **Office of Water** * Office of Ground Water & Drinking Water * Office of Wastewater Management - **Office of Research & Development** * National Risk Management Research Lab * National Homeland Security Research Center * National Center for Environmental Research
User Community - American Water Works Association Research Foundation - Utilities
Other Federal Agencies - DOE (e.g., Strategic Center for Natural Gas) - DOT (e.g., Office of Pipeline Safety) - DoD (e.g., Civil Engineering Research/Industrial Ecology) - NSF (e.g. Civil & Mechanical Systems)
Other Stakeholders - SIM Device & System Manufacturers; Inspection Services - Pipe Manufacturers - Academia - Other Domestic & International Research Foundations

IMPACT OF EPA SCIENCE ON THE ISSUE

Prevent classes of high risk main breaks and adverse effects

Reduce lost water by more prompt discovery and location of leaks

Improve performance and cost data for new SIM technologies

Accelerate SIM technologies development for drinking water mains

Improve asset management capabilities

Stimulate research and collaboration

Improved structural integrity data availability may assist development of condition assessment/service-life models and precision repair/rehabilitation technology

Science and Innovation to Protect Health and the Environment